Radical Alliances

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Thanks to the interdisciplinary milieu of the Atlas Institute (Alliance for Technology, Learning and Society), a swarm of shape-changing robots moved furniture around a room, opening up new haptic ideas for virtual reality. Located at the University of Colorado Boulder, Atlas provided the ideal research environment for RoomShift (see cover and Figures 1 and 2). With academic pedigrees from Tokyo to Austria, a diverse team of graduate and undergraduate students and their professors all contributed to the project.

Ryo Suzuki, originally from Japan, recently finished up his Ph.D. at the Atlas Institute with an emphasis in a human–computer interaction. As one of the RoomShift lead researchers, Suzuki took inspiration from shelf-moving robots in warehouses and imagined a way to increase their roles in everyday environments like schools, offices, or business labs.

"My idea was, what if the robots can deconfigure everything in the environment—like a room or offices or home—to assist people's lives," Suzuki said. "Say, for example, if the robot can rearrange the classroom based on how many students are there, or how many are in the workshop. That was always our starting point."

In most cases, VR allows a user to wear a headset and journey through virtual environments, but without really interacting much with the physical environment in the room around him. Whenever the user walks around or tries to touch the virtual objects, the illusion is broken because he cannot really touch anything. With all the advances in computer graphics, displays, and tracking technologies, users begin to feel impoverished without any equivalent ability to interact with objects in the VR environment.

However, what if robots could be in the room to help augment this problem? The robots could "track" how the user physically moves while he watches the virtual world in his headset. The robots could move around in the physical space, picking up chairs and tables, adjusting them or repositioning them, all according to how the user navigated the room. The robots could, thus, augment the virtual scene by rearranging the physical space in real time. Then, the user could sit on the chairs, lean against them, place his hand on a table, or interact with the furniture just as he would in the real world. This adds a whole new type of haptic component to the VR experience.

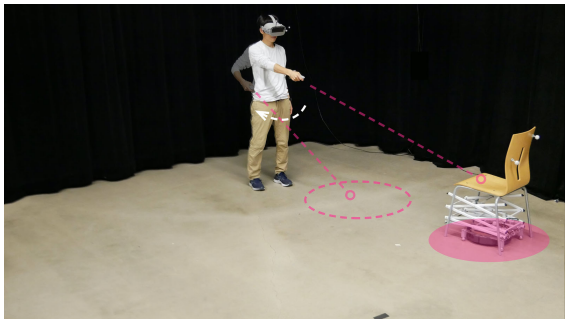

FIGURE 1. RoomShift robots pick up and move furniture across the room, creating a haptic environment for VR. (Used with permission.)

"If we can deconstruct the physical environment to match to the virtual world, then the virtual world suddenly becomes the physical," Suzuki said. "Whenever you touch the wall, whenever you touch the desk, whenever you touch the chair, the actual physical chair is there. That's the energy, or motivation, of the project."

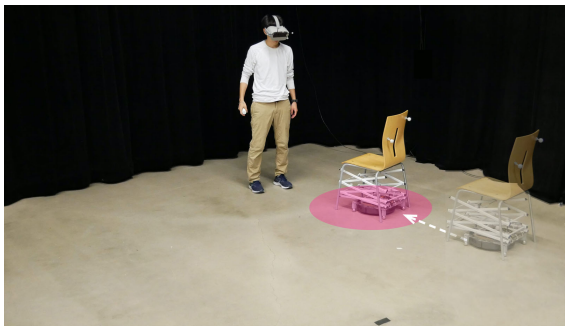

FIGURE 2. RoomShift robots pick up and move furniture across the room, creating a haptic environment for VR. (Used with permission.)

0272-1716 © 2021 IEEE
Digital Object Identifier 10.1109/MCG.2021.3086337
Date of current version 12 July 2021.

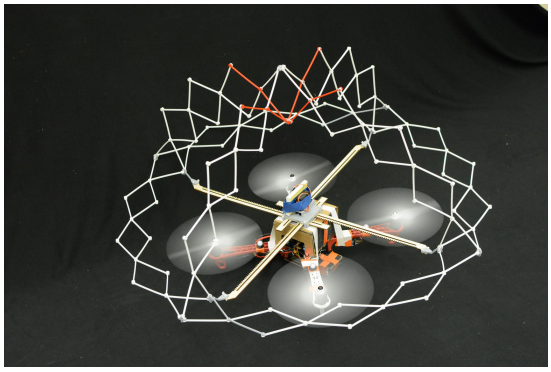

FIGURE 3. PufferBot features a drone that expands like a puffer fish so its propellers will not get damaged. (Used with permission.)

Institutional Innovation

A relatively young facility, Atlas was created in the late 1990s for the purposes of interdisciplinary research and radical creativity. These are not buzzwords. Each faculty member that runs a lab, or a group, has a tenure home in another department. Atlas faculty attend the same meetings, their students collaborate with each other, and everyone has access to research streams in other departments. On any given day, one might find computer science, chemistry, mechanical engineering or architecture faculty, or their students, all contributing to a project. Art and technology also play a huge role.

All of which creates a perfect place to transform a human–computer interaction for virtual reality. For the RoomShift project, the team simply went upstairs to the performance stage and learned from computer scientists that were using 3-D motion-capture technology to track modern dancers, and then deployed the same system to control the robots in the RoomShift project. Atlas also includes the equivalent of a maker space, so if the team needed quick access to a 3-D printer, a laser cutter, or anything to fabricate materials for the robots, they could do so. The interdisciplinary mission of the Atlas Institute facilitates and encourages such collaboration.

"When you start to work on this intersection between the digital and physical, where you could be part of different departments like mechanical engineering or computer science in your research, it's really just attractive to be in an institute where that's embraced," said Daniel Leithinger, a UC Boulder Assistant Professor of Computer Science on the RoomShift team who grew up near Linz, Austria.

A spirit of collaboration exudes from the whole RoomShift project, indicative of a fun, interdisciplinary approach that could never have emerged in a single, compartmentalized curriculum. Along with Suzuki and Leithinger, other Atlas denizens on the team included Assistant Professors of Computer Science, Dan Szafir and Ellen Yi-Luen Do, along with their respective students, Hooman Hedayati and Clement Zheng, plus Atlas director Mark D. Gross and James Bohn, who was just finishing high school at the time. In addition, both Gross and Leithinger were on Suzuki's Ph.D. committee. All eight researchers coauthored a resulting paper that was published in the *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*.

After Suzuki completed his Ph.D. last year, he then went right into an Assistant Professor job at the University of Calgary Department of Computer Science. He still sings the praises of his alma mater.

"I learned stuff that couldn't happen if we were not working at the Atlas Institute," Suzuki said. "I think of it as the core, the home place of almost all the projects that I did."

Scaling Up

Looking ahead to the future, RoomShift reveals the degrees to which distributed swarm robots can help make such systems more robust, modular, and scalable, rather than trying to build one big complicated system. For example, to further develop the shape-changing aspects, another project, PufferBot (see Figure 3), featured a drone that expanded like a puffer fish so its propellers would not get damaged when the drone came too close to obstacles or humans.

In any case, RoomShift shows that if you want to build up an environment that synchronizes with your digital environments—like with your VR scene for example—trying to render everything might not be feasible. Instead, you can reappropriate existing objects—in this case, by moving chairs and tables around—and thus reconfigure the room.

"Rather than trying to replicate everything, we could build these robots and actuators that can integrate with the environment we're already in," said Leithinger. "I think that's a really powerful concept that we could push much, much further."

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